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THREE-DIMENSIONAL TARGETS FOR THE POP-UP DEVICES M31A1 AND 3C52

Final Design and Evaluation Report

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Contract N61339-66-C-0077

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ORLANDO, FLORIDA
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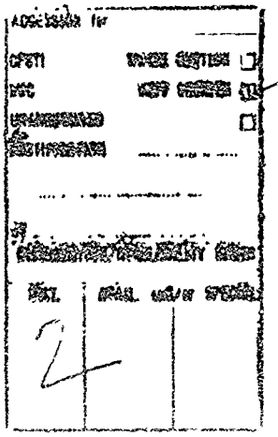
ABSTRACT

The development of targets filling a volume of space equal to that of a soldier in the kneeling firing position is described. The targets were designed for use with a pop-up target holder, devices M31A1 and 3C52 using a vibration sensitive hit switch. Three forms of targets, each of linear polyethylene, are described. When viewed from the front, all targets presented the silhouette of the planar kneeling target which is currently being used. The target depth (8 inches) was developed by a projecting sheet welded to a planar board in the case of the "T" type target. A formed Aggressor target was vacuum formed to an 8-in. depth with features similar to an aggressor soldier. A third type of target developed was a Half-Round with depth developed by a half cylinder section in the body and a trapezoid cross-section in the head.

High response accuracy was obtained with the Aggressor form and the Half-Round target. The "T" type could not be fabricated in a form suitable for the purpose. Response accuracy above 98% was obtained with Half-Round and Aggressor targets, but difficulties with the target holding device prevented the assignment of a particular accuracy figure as characteristic of the targets. Realism can be obtained with the targets described by using decals, coating, and by use of colored plastic.

Field evaluation at training sites is recommended for the Half-Round and Aggressor formed targets.



FOREWORD

A continuous problem exists to develop a realistic, economic and durable target for the training of combat troops. The expanding field of plastic applications has made it possible to up-grade many standard low cost target systems. Cardboard targets, though reasonable, have a short useful life and have environmental limitations. In an earlier study under Contract N61339-1820 different materials were examined in an effort to up-grade the silhouette targets and backboards for mounting open cell polyurethane foam 3-dimensional targets. Polyethylene target replacements proved to be a significant advancement as they tolerated extreme weather conditions and have a life expectancy five times greater than that of cardboard. The present study shows that polyethylenes are easily formed into the configuration of a man from the front as well as the side view. The effectiveness of the various molded target configurations is presented in this report. Additional efforts are scheduled on the new material targets, particularly field evaluation tests at Training Center Firing Ranges. The results of field evaluations will provide a basis for considering the targets for U.S. Army and U.S. Marine Corps standardization.

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INTRODUCTION

The pop-up type target has been accepted as a standard training device in training military personnel to fire a rifle effectively. Originally, this type device was operated by a timing mechanism which returned the target to a horizontal, non-visible position after a certain time period. The scoring of hits was then determined by a visual count of holes in the target. A later type device, the 3C52 mechanism, contains a provision for automatically lowering the target when a target hit was scored. The operation of this device is triggered by a vibration sensitive microswitch mounted on the target-holding clamp; when a bullet hits the target the switch is actuated by the vibration of the target.

With the introduction of the 3C52 device, a need arose for an improved target. The response of the early targets was found to be adversely affected after having been subjected to high humidity or rainfall. A program, Army Project No. 1-M-0-13001-A-039, conducted by Rock Island Arsenal's laboratory, resulted in the specification of the current fiberboard target. These targets are now being procured and are required to provide 24 kill responses for 25 hits by 30 caliber bullets. In actual use it is found that the response accuracy is approximately 80% after 400 rounds. (See Test and Evaluation Report, Contract N61339-1820, 29 Aug. 66.)

During a target material development contract, N61339-1820, linear polyethylene targets which provided response accuracies as high as 98.9% for a 960 hit firing test were evaluated. The purpose of the project, on which this report is written, was to develop targets suitable for training exercises, utilizing the M31A1 device in flanking fire situations.

The project was initiated to develop a three-dimensional target which would occupy the volume of a man's torso and could be mounted on the M31A1 and 3C52. Such a target should be suitable for use in tactical field exercises.

The final test of any target used with the pop-up device is its ability to actuate the device when hit by a bullet. The M31A1 and 3C52 rely upon a vibration or shock actuated device to sense the bullet striking the target. There is no known means of measuring the

ability of a target to perform in the pop-up device by a laboratory type test. Therefore, each target design must be subjected to range testing.

STATEMENT OF THE PROBLEM

The targets developed during this contract were to have a frontal silhouette identical to the kneeling target as shown in Rock Island Arsenal drawing No. 8426438. The weight of the developed target should not exceed 2.75 lbs. which is the maximum weight the M31A1 and 3C52 pop-up devices can lift. The response accuracy of the target should at least meet the existing specification for the fiberboard kneeling target. The new targets should be three-dimensional with a profile depth of 8 in. or 9 in.

The target would be required to fit into the current device clamp and to function with no alteration of the device.

METHOD OF PROCEDURE

There were certain concepts which influenced the design of the target. These guiding concepts were based upon observations which had been made during Contract No. N61339-1820. Flexible materials or structures had poor response while rigid structures had improved response. It was assumed that a material or structure which required the bullet to transmit a greater part of its energy before passing through would be capable of affording a target of superior performance. Forms had to flex as units; those containing sections which may flex independent of the remainder were avoided. Similarly, axes about which a part of the target could bend were avoided.

Two types of fabrication, vacuum forming and welding, were used. The design of a target for vacuum forming was followed by production of a mold to be used for part forming. In all instances male molds were used. Molds were made from wood, wood covered by epoxy and from Hydrocal plaster. These types of molds were used because the number of parts to be made per mold was limited.

In practice, forming the parts was found difficult when using these molds. The heat of the heavy (.090 in.) plastic sheet used in constructing the target, dried the wood and caused shrinkage and slight mold deformity during the forming of the first few parts. Once the shrinkage had begun, mold seams and joints opened and parts formed subsequently adhered to the mold, invariably destroying the mold when the part was removed. The Hydrocal molds were affected in a similar way. In this case, where a mold was made from several pourings into a cavity, the joints of the successive layers were weak spots and had a tendency to crack when heated by vacuum-forming.

The range testing of targets was accomplished at the Naval Training Device Center. Targets were mounted in a M31A1 and 3C52 and fired at from a distance of 25 to 50 yards using 30 caliber Spitzer pointed bullets in an M-14 Rifle. The target-to-rifle-angle was varied during the test to include aiming at the frontal silhouette, a side view of the target and an intermediate angle. Patterns were fired at local areas of the target to determine if any target areas could be distinguished by performance.

Unfortunately, there were no means by which the performance of the device, independent of the target, could be established. In fact, it was necessary to

assume that the device was in good working order and this assumption was always based upon the performance of the target. When targets were performing poorly the device would be overhauled and a change made in the vibration sensitive microswitches.

The device in use performed well during the first range tests. After this time the prototype targets being used ranged from poor to excellent in performance. These differences in target performance suggested that the device was operating well. Later in the program the performance of all targets, including those that had been excellent during previous tests, became fair or poor. The device was overhauled and new microswitches installed. The performance of all targets improved after this was done

The vibration sensing microswitch, used in the pop-up device, has contacts close in its rest state. When vibration or shock is sensed by the switch, these contacts are opened. The manufacturer's quality control test of these switches is performed by mounting the switch on a revolving wheel and noting the r.p.m. at which the switch opens. Switches opening between 3-5 g's are rated as acceptable.

The microswitches utilized should have been tested and numerically specified before and after being used on the range. Since this was not done, the test was less precise than otherwise would have been the case.

DISCUSSION

"T" Type Target. The "T" type target was constructed of a sheet of linear polyethylene, essentially identical in form to the kneeling target, onto which an 8-in. wide sheet of plastic was welded to the centerline of the backboard and making a right angle with backboard plane. This 8-in. projection terminated three to five inches from the bottom edge of the target so as not to block the seating of the bottom edge of the backboard in the target clamp. A "T" type target is illustrated in Figure 1.

The initial target tested was fabricated by cutting a formed plastic kneeling target in half at the vertical centerline. These two halves were joined to a sheet of plastic inserted between them. The welded assembly then presented a "T" type target configuration. All elements were of .075 in. to .080 in. linear polyethylene. In testing this target on the firing range, the welded joint separated. It was also noted that bullets striking the projecting element of the target had a tendency to key-hole through the backboard portion.

A second linear polyethylene "T" type target was fabricated. This target was made by joining an 8-in. wide section of sheet to the length of the centerline of a sheet of plastic with the silhouette of a kneeling target. Welding beads were applied on both sides of the weld joining the two sections.

The performance of this target and the first target was the same; the weld separated after several rounds were fired into the weld line.

A third "T" type target was then designed and fabricated with no welded joints. A single sheet of plastic, approximately 40 in. x 36 in., was folded at the centerline so that it appeared to be 18 in. x 40 in. Each 40 in. edge was then folded (one in a clockwise direction and one counterclockwise) to provide a 9-3/4 in. width normal to the original plane. This provided a "T" structure with a double thickness in the projecting part. To seat the target in the clamp it was necessary to cut it at the bottom edge, where the projection met the clamp. The target was fabricated from a sheet .063 in. thick and the target weight was 2.81 lbs.

When tested, this target had a tendency to whip. Increasing the thickness of the sheet would result in an

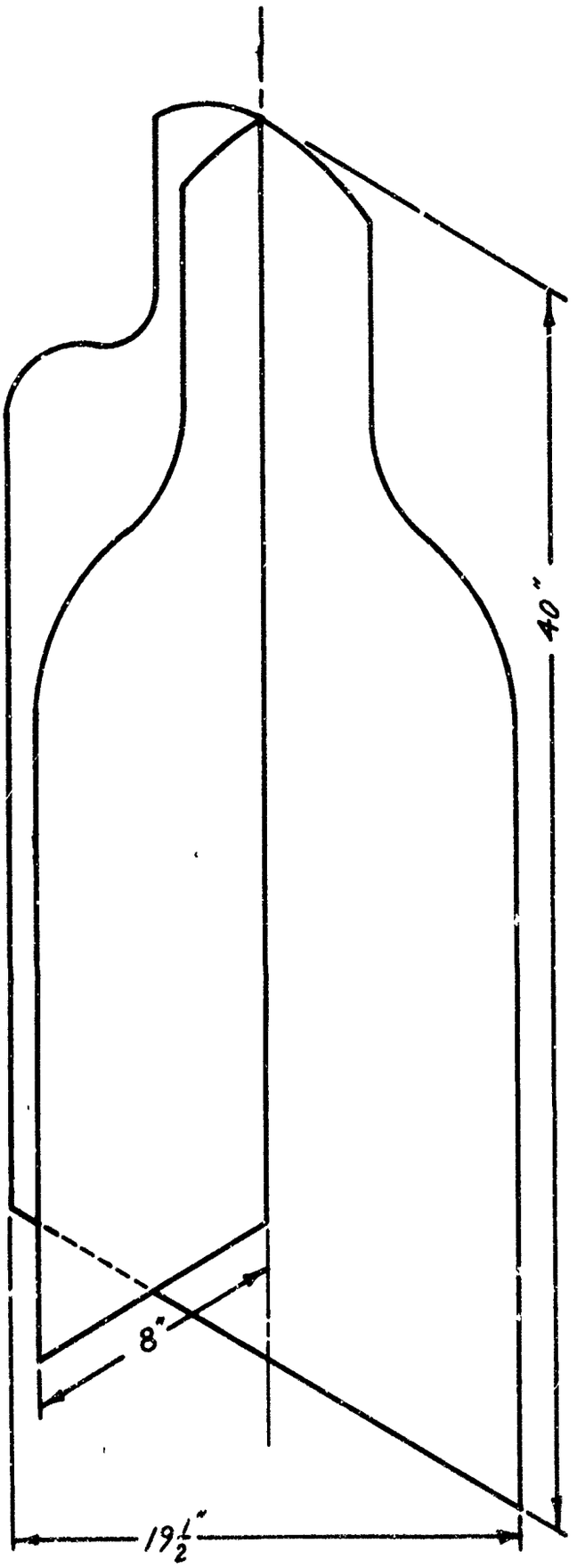

Figure 1. "T" Type Target

excessively heavy target. Additionally, the "T" type target was conceived as a target which would carry a form element to simulate the appearance of an aggressor soldier. This would increase the weight required by 1 lb. For these reasons this unit was not considered a satisfactory target element.

This configuration was abandoned at this point, since there did not appear to be a design or fabrication method that would lend itself to the development of a suitable "T" type target.

Three-Dimensional Aggressor Target. The three-dimensional aggressor target was to approximate the silhouette of the kneeling target as shown in Ordnance Drawing C8426438. The target was to provide a representation of the aggressor soldier as depicted in FM30-101-C1, 27 April 1962. Uniform details were taken from Figure 13 of this Field Manual, which illustrates the Senior Sergeant of a Mechanized Rifle Division. The target was to be life size and limited to representing the torso of such a soldier. The depth of the target was to be 8-in. An aggressor target is shown in Figure 2.

The target material was to be linear polyethylene and the part was to be made by the vacuum forming over a male mold. The target was to be designed to allow for nesting in storage.

The initial mold made had a large part of the depth developed by the draw of the sheet at the edge of the form. Thus, a draw of more than 6 in. occurred in a width of less than 1-1/2 in. This draw resulted in a very thin edge. The edge sections thinned out to less than 50% of the initial sheet thickness. The target-holding clamp grips the bottom edge of the target for a length of approximately 14 in. The length of the bottom edge of the target is 28 in. Therefore, a large part of the target did not receive stiffening from the clamp.

Testing a 75-mil target on the firing range indicated that response accuracy was poor. The target had a response accuracey of 78.7% for 300 test rounds.

When the target was examined in the device clamp, it was apparent that the sides of the target were able to flex or vibrate independently of the mass of the target. It was first thought that this probably was responsible for the poor target performance. This effect, however, was due to the thin gauge of the drawn plastic at the

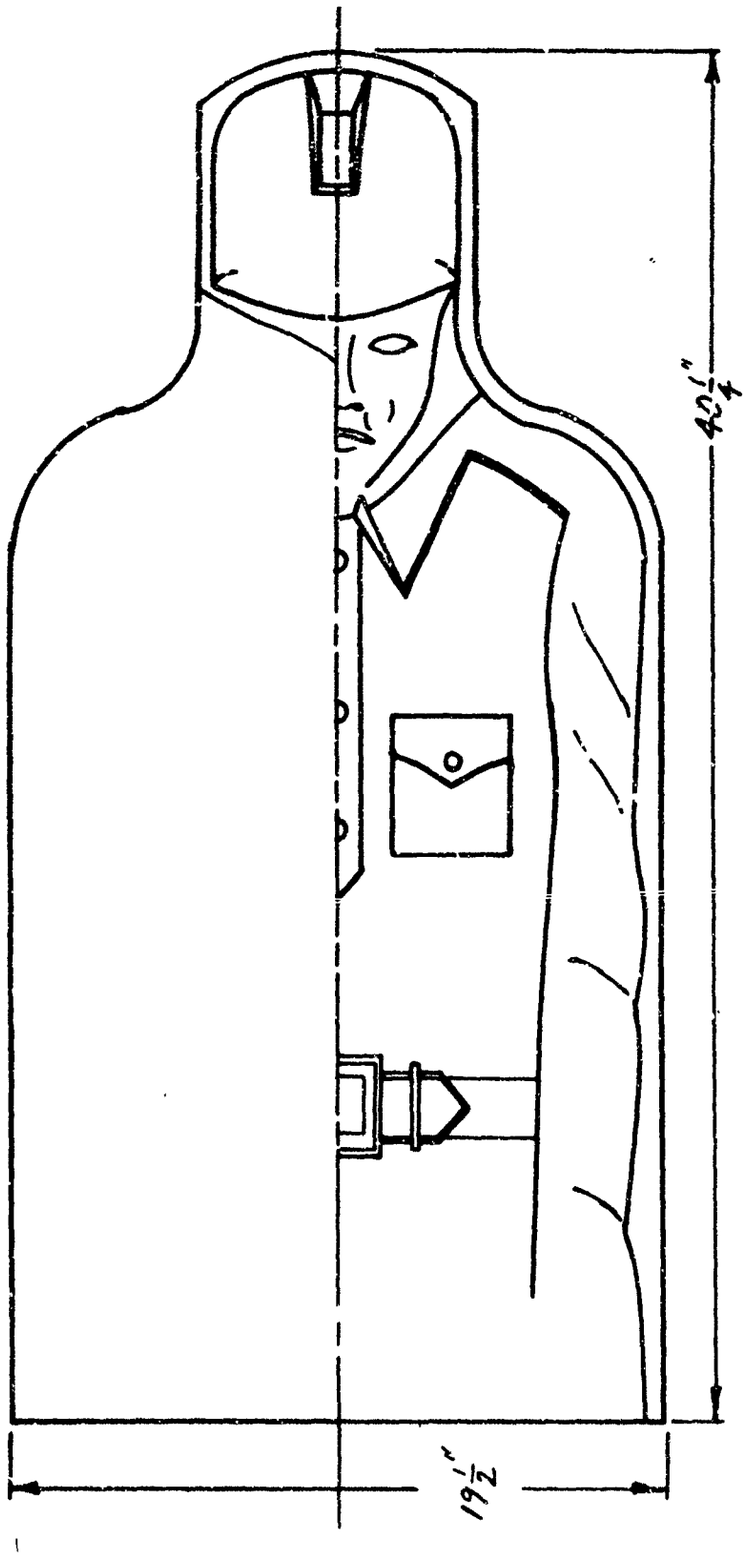

Figure 2. Aggressor Target

sides (outside arm sleeves), the fact that this surface had practically no formed surfaces (was flat), and the small size of the target holding clamp in relation to the target. The response accuracy of a .093 in. aggressor target of this type is detailed in Table 1.

At this point in the program it was not known if a target of the configurations proposed could perform satisfactorily in the existing clamp. This was in doubt primarily because of the small length of the target clamp relative to the length of the bottom edge of the target.

To ascertain if the performance of the target would be improved by providing additional rigidity to the form, modification of the target described above was undertaken.

A target formed on the same mold and of the same gauge sheet was cut so that a 3/4-in. flange extended around all the edges of the target, except the bottom edge. This was incorporated to increase the integral rigidity of the target. Additionally, two creases were formed with hand held tools into each sleeve of the aggressor target. After these modifications the target was then tested on the range.

The range testing was conducted with 30 caliber Spitzer type pointed bullets. Rifle-to-target-distance was approximately 25 yards. The target weight was 2.27 lbs. 400 Rounds fired into the target resulted in 397 hits which activated the device and 3 hits which did not activate it. The tabulated data for this test is presented in Table 2.

This test demonstrated that the existing device target clamp could be used to hold a flanking fire target and allow for good hit response accuracy. Also, the test established the importance of forming creases at the side sleeve surfaces of the target. These tests were interpreted as verification of the value of the flange in enhancing the performance of the target.

The changes in the targets which were undertaken at this time involved the production of a new mold. This mold was to provide for a flange of 1/2-in. around all peripheral edges except the bottom. Additionally, creases were placed in the sleeves to provide stiffnes for the surfaces of the target. To reduce the drawing at the sides and edges of the target, which tended to provide a thin gauge at these surfaces, the body of the target torso

TABLE 1. RESPONSE ACCURACY RECORD OF .093-IN. THICK AGGRESSOR TARGET (INITIAL DESIGN)

Shooter's View of Target	Hit Location	Number of hits	Number of Kills*
Front	-	20	20
	Edge	20	19
	Body	20	20
	Face	100	86
Profile	-	60	55
Angular		60	49
		280	249

*A Kill is a bullet hit that activates the target device.

TABLE 2. RESPONSE ACCURACY OF .075-IN. THICK AGGRESSOR TARGET (SECOND DESIGN)

Shooter's View of Target	Hit Location	Number of Hits	Number of Kills*
Front	Face	180	179
	Helmet	20	20
	Body	40	40
Angular	Helmet	10	10
	Face & Shoulder	10	10
	Shoulder	40	40
	Body	20	20
Profile	Shoulder	40	40
	Head	40	38
		400	397

*A Kill is a bullet hit that activates the target device.

was rounded somewhat so that the draw was reduced at the edges.

The average weight of the twelve 90-mil aggressor targets before coating was 1160.3 grams or 2.55 lbs. The maximum target weight was 1190 grams and the minimum weight 1137 grams. The targets delivered during this contract were formed from natural color polyethylene. To afford realism to the targets they were coated with a vinyl green and skintone paint. To improve adhesion, the targets were wiped down with solvent to remove any release agent or surface contaminant. A rubber cement was then applied to the surface of the target. The vinyl paint was applied over the dried rubber cement.

In practice, the coating did not perform satisfactorily. The paint tended to fracture in the area where a bullet penetrated the target.

In producing a target formed to represent an aggressor soldier, the target should be made from plastic that is extruded with the color of the aggressor uniform. The skin color can be obtained by applying a heavy coating of an organosol colored to skin tone. The weight of this coating over the face area would not be excessive, whereas a coating over the entire target would be excessive in weight.

The range testing accuracy of this target was doubtful due to the condition of the pop-up target holding mechanism. For example, the delivered end item tested out as giving a 90.4% hit accuracy for 260 rounds. Subsequently, the M31A1 and 3C52 device was overhauled and the same target had 95.5% accuracy for 210 test rounds. This variance is too large to be within the limits of normal deviation.

Similarly, an identical aggressor target element without paint coating on initial testing gave 340 hit responses for 340 target hits. When the device became suspect, this target had 92.1% response accuracy for 560 test rounds. This data illustrates the lack of precision in the range test.

During the tests reported on, the direction of fire at the target was varied and firing was accomplished at specified target areas to determine if the response of any area was poor relative to other areas. The areas of approximately three or four inches diameter below the shoulder top on either side of the head, consistently

gave response averages below that obtained for the rest of the target. No explanation for this difference is available. The rigidity of the suspect surface was excellent and it did not appear that a shock to this surface could be localized. There was no basis for distinguishing between the suspect surface and other surfaces of the target except for that noted in range testing.

Data obtained in testing two targets of the final design are given in Tables 3 and 4.

TABLE 3. RESPONSE ACCURACY OF AGGRESSOR-FORMED TARGET (FINAL DESIGN)

Shooter's View of Target	Number of Hits	Number of Kills
a)* assorted	340	340
b) side	80	70
c) opposite side	180	175
d)	80	77
e) side	40	37
f) angular	180	157
g) angular	100	97
h) front	100	96
i) angular	100	94
j) side	100	96
k) angular	100	95
l) opposite angular	80	76
m) side	60	60

Response Summation	Hits	Kills	Percent
a)	340	340	100
b) - f)	560	516	92.1
g) - m)	640	614	95.9

*Data are listed in time sequence in which it was obtained. Data listed on lines d, e and f was obtained on the same day. Data from lines g - m were obtained after device was overhauled.

TABLE 4. RESPONSE ACCURACY OF AGGRESSOR-FORMED TARGET (FINAL DESIGN)

Shooter's View of Target	Number of Hits	Number of Kills
a)* angular	20	15
b) front	20	18
c) angular opposite	80	76
d) angular	60	53
e) profile	80	73
f) angular	80	77
g) opposite angular	140	128

Response Summation	Hits	Kills	Percent
a) - d)	180	162	90.0
e) - g)	300	278	92.7

*Data listed on lines e - g were obtained after the device was overhauled.

Half-Round Target. This target was designed to have an 8-in. depth. The depth was developed as part of a cylinder of 9-1/16 in. radius. The surface of the cylinder utilized had a chord of 18 in. and a height of 8 in. The body of the target conformed to the cylinder section. The head section was also 8 in. in depth. In cross-section the head was a trapezoid of 7-1/4 in. base and 7/8 in. width at the top. The height was 8 in. The target was designed to have a 3/4 in. wide flange along the body perimeter and a 5/8 in. wide flange at the perimeter of the head. This target is illustrated in Figure 3.

This target, made from .090 in. thick plastic, functioned very well. (See data in Table 5.) However, due to the 9-1/16 in. radius of the body, it spread out when inserted into the 15 in. radius of the M31A1 and 3C52 target holding clamp. This effected a change in target dimension so that when viewed from the front it had the appearence of a trapezoid.

The initial range test of a 90-mil target formed to the half-round configuration described above resulted in 365 hits with 364 device responses for a response accuracy of 99.7%.

Modification of this target was initiated to incorporate several changes in the target design. Firstly, it was deemed desirable to have the bottom edge of the target formed to the same radius as the target holding clamp. Additionally, a reduction in flange width was attempted. The original mold was modified to effect these changes. However, when attempts were made to form the part, the mold was destroyed by heat of the plastic sheet. (The mold was of wood.) A new mold was made with Hydrocal plaster and this was used to form the parts desired. However, there was an error in mold design and this resulted in a part that was not in conformity to the kneeling target silhouette.

Finally, a mold was made to produce a target in the form of the original target but modified so that the bottom edge had a radius of 15 in. for a length of 14-1/2 in. The results of limited testing of this final target are given in Table 6.

A decal designed for this target is made of 5-mil vinyl film with an elastomer coating protected by paper on the back of the vinyl. To attach the decal to the target the paper is peeled off and vinyl pressed onto the surface of the target. The color scheme of an aggressor soldier and the skin tone is obtained with vinyl colors.

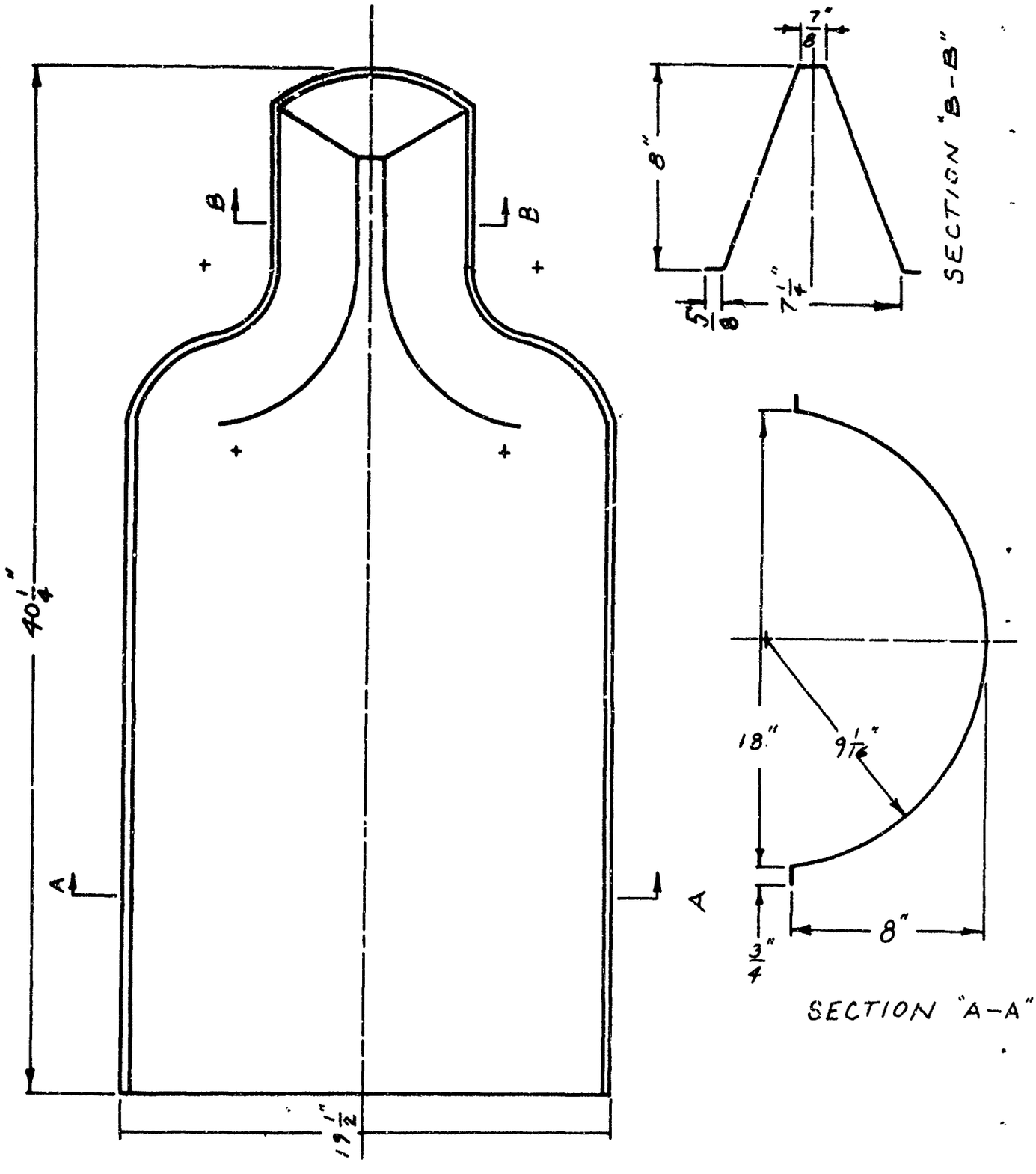

Figure 3. Half-Round Target

TABLE 5. RESPONSE ACCURACY OF TWO HALF-ROUND TARGETS (INITIAL DESIGN)

Shooter's View of Target	Hit Location	Number of Hits	Number of Kills
Front	Head	20	20
	Shoulder	20	19
	Body	20	20
Angular		25	25
Profile		20	20
Front		80	80
Second Target			
Front		40	40
Angular		40	40
Flange Cut-Off			
Profile		60	60
Front		60	60
Response Summation	Hits	Kills	Percent
	385	384	99.7

TABLE 6. RESPONSE ACCURACY OF HALF-ROUND TARGET (FINAL DESIGN)

Shooter's View of Target	Number of Hits	Number of Kills
Angular	40	36
Front	80	78
Angular Opposite	40	39

Response Summation	Hits	Kills	Percent
	160	153	95.6

RESULTS

The three target designs, mentioned under disucssion, "T"-type, aggressor formed target and half-round, were evaluated.

The "T"-type target was eliminated due to the failure of welded joints and the impossibility of obtaining high response accuracy with this target form in the existing clamp.

The aggressor form and half-round targets were both capable of delivering exceptionally high response accuracy. However, one pop-up device was used and when this device became suspect, all test targets performed poorly. After repairs and overhaul of this device, performance improved but did not equal that originally obtained.

As has been discussed earlier in this report, the sensitivity of the vibration-actuated microswitch, located on the M31A1 and 3C52 device, is believed to be of primary importance to the results obtained on the firing range. The performance of the device can become suspect when bullet hits on one side of a target do not result in kills as frequently as those on the opposite side. Occasionally, the response of a target will not be equal to the response previously obtained on the same target, and creates suspicion of the device. In such an instance the only recourse has been to overhaul the device and replace vibration sensitive microswitches with new ones. It is unfortunate that the microswitches used did not have numerical test values which could be related to the switch.

Difficulties of the type described above did make some of the test results questionable. However, the ability of a half-round and aggressor form target to record approximately 350 hits accurately must be attributed to the target, since this type of performance could not be obtained with targets not suited to the device.

Tests were conducted to determine if certain areas of the targets were less responsive than others. Shoulder regions of the targets proved to be less responsive. This was particularly noticeable when the device was not functioning properly. These regions are a part of the slope of the shoulder of the half-round target and a small surface on the front of the aggressor target in the

shoulder region. No other target areas could be designated as being less responsive than other areas of the target.

The target configurations produced during the contract may have suffered slightly in range evaluation due to the condition of the clamp. The clamp used was a shop fabricated version of the actual clamp. It was made of aluminum and was more flexible than the actual clamp would be. It was used in all the testing reported here, and though it was never suspected as being a factor, being different from the design part warrants mentioning.

CONCLUSION AND RECOMMENDATIONS

The project reported on has demonstrated that the existing pop-up target mechanism, without any modification, can be used with targets which occupy a volume of space equal to that of a man in the kneeling position when firing a rifle.

Two types of targets were found to be suited for this purpose. One target, Aggressor, formed in the figure of an aggressor soldier, and another, Half-Round, formed from geometric sections and a decal, depicts an enemy soldier by stylized coloring of the decal.

Both targets have been demonstrated to afford high response accuracy in the pop-up device. A third target, "T" Type, constructed by welding a projection onto the form of a plastic kneeling silhouette target, was not suitable due to poor response and bullet destruction of the weld.

Much of the work accomplished during the course of this project was dependent upon the testing of development targets mounted in the pop-up device at the firing range. As has been indicated, these tests are dependent upon the performance of the device and indications are that this performance is not a constant factor.

To improve the test reliability, it is suggested that a set-up duplicating or resembling that which is now being used by the manufacturer of the microswitches be incorporated as a part of the test apparatus for range testing targets in the pop-up device. Then, by measuring the force required to open the microswitch switches before undertaking a range test, and measuring this force after a range test, any changes in the switches would be detected.

The Aggressor and Half-Round targets have both been demonstrated as being suitable for use with the M31A1 and 3C52 pop-up device. It is recommended that they be given field evaluations by training commanders to ascertain their value as training aids.

The Aggressor target allows realism to be achieved when the target is formed from a forest green color and the face of the target is coated to simulate a skin tone. Realism can be obtained with the Half-Round target by a technique similar to that suggested for the Aggressor or by the use of a decal mounted on the target.

The advantages of having a target in the form of a man cannot be simply assessed. One major contribution this provides is the training of personnel to fire upon lifelike targets, which is a requirement for effective military action. Training with a target with an inanimate appearance may teach a trainee to hit a target but not necessarily to hit a man.

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11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
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13 ABSTRACT

Efforts to develop a three-dimensional realistic target are described. Targets were fabricated from polyethylene for use with vibration sensing pop-up target devices. The frontal silhouette was that of the kneeling target now in use. The depth of the figure was eight inches. Two target configurations which were found to be suitable were tested during the contract. These targets were a half-round of a soldier with regular geometric sections suggesting head and body. A decal covering the plastic target provided color and detail. The Aggressor Formed target was made to have facial details (eyes, nose, etc.) and uniform detail (pockets, sleeve creases, etc.) molded into the part. Both of these targets were capable of providing high response accuracy when mounted in the pop-up device.

A "T" type target fabricated by welding or forming a plastic sheet into a "T" configuration was not found to be usable.

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